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Research Article

Textile Nanocomposite of Polymer/Carbon Nanotube

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Abstract:

Carbon nanotube (CNT) possess outstanding electrical, mechanical, anisotropic, and thermal properties to be employed in several material science applications. Polymer/carbon nanotube forms an important class of nanocomposites for textile uses. Different techniques have been used to develop such textiles including dip coating, spraying, wet spinning, electrospinning, etc. Enhanced nanocomposite performance has been attributed to synergistic effect of polymer and carbon nanotube nanofiller. Textile performance of polymer/CNT nanocomposite has been potentially important for flame retardant clothing, electromagnetic shielding wear, anti-bacterial fabric, flexible sensors, and waste water treatment. In this article, researches on application areas of polymer/CNT in textile industry has been reviewed. Modification of nanotube may lead to variety of further functional textiles with different high performance properties.

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1. Introduction

Textile nanocomposite has gained considerable topical research interest [1-3]. Carbon nanotube (CNT) is most widely used nanofiller for polymer nanocomposite [4-8]. Polymer/CNT nanocomposite have captivated recent research attention due to wide range of technical applications [9-13]. Owing to lightweight and distinct physical and chemical properties, polymer/CNT nanocomposite are promising candidates for textile materials. Various techniques have been used for fabricating polymer/carbon nanotube nanocomposite with unique properties. These nanocomposite-coated/integrated textiles have various applications in wearable clothing, military garments, and smart textiles. This article basically addresses applications of polymer/CNT nanocomposite in textiles such as non-flammability, EMI shielding, sensors, anti-microbial action, and textile water treatment.

2. Carbon nanotube

Elemental carbon has capability to form different structures in sp^2 hybridization such as carbon nanotube, graphene, nanodiamond, etc. [14-20]. First time tubular carbon structures were discovered by Iijima in 1991. CNT has cylindrical nanostructure. The cylindrical carbon molecules own several distinctive properties such as thermal conductivity, mechanical, and electrical properties. Fig. 1 shows various classifications of carbon nanotube as single-walled nanotube (SWCNT), double-walled nanotube (SWCNT), and multi-walled nanotube (MWCNT). SWCNT possess diameter of 1 nanometer and length much longer than its diameter. MWCNT consist of several tens of graphitic shells and high length/diameter ratio. Several structural models have been proposed for carbon nanotube. Numerous techniques such as chemical vapor deposition (CVD), arc discharge, laser ablation, carbon monoxide disproportionation, etc. have been adopted to form carbon nanotube.

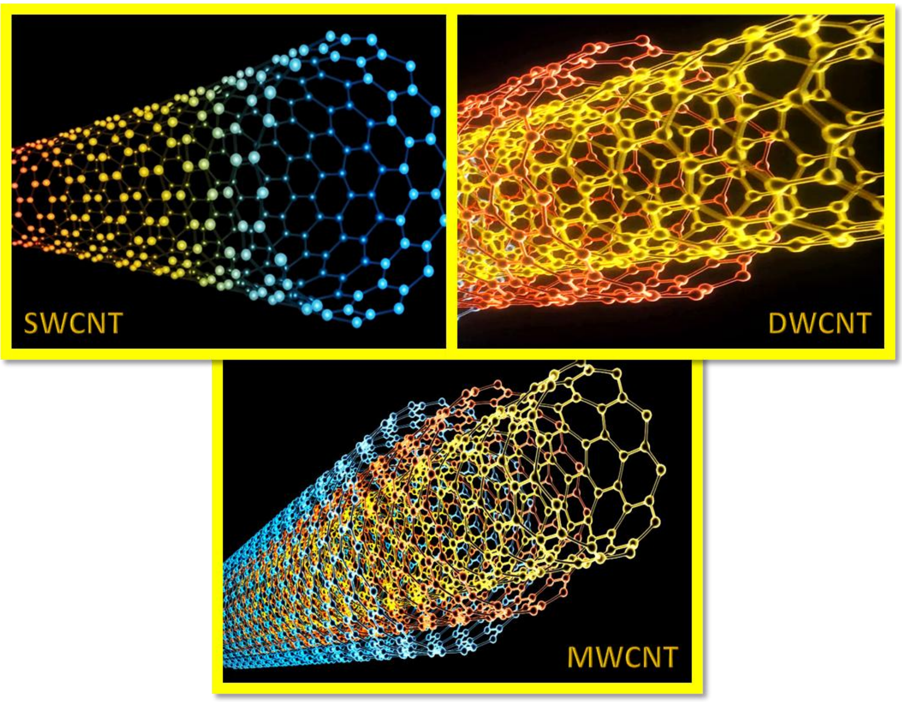

Fig. 1 Carbon nanotube.

3. Polymer/carbon nanotube nanocomposite

Advances in nanotechnology has introduced various types of polymeric nanocomposite for technical applications. Polymer/carbon nanotube forms an important class of nanocomposites in this regard [21-28]. Enhanced nanocomposite performance is actually due to synergistic effect of polymer and carbon nanotube (CNT). High specific surface area, strength, and chemical inertness render CNT as an efficient nanofiller. Both single- and multi-walled carbon nanotube have been used as nanofiller. Several viable and effective approaches have been adopted for the fabrication of polymer/carbon nanotube nanocomposite. Owing to outstanding characteristics, these nanocomposite have received widespread interests in aerospace, electronics, construction, membrane technology, and textiles.

4. Polymer/carbon nanotube in textile

Polymer/carbon nanotube nanocomposite have remarkable structural, electrical, mechanical, and thermal properties pertinent to several fields including textile, aerospace, electronics, construction, etc. There are wide range of research activities to find applications of polymer/carbon nanotube in textile trade [29-31]. Fig. 2 shows various implications of polymer/CNT nanocomposite in textile industry. The nanocomposite has been applied to textile fabrics using various techniques such as dip coating, spraying, wet spinning, electrospinning, etc. Non-conducting polymers such as epoxy, nylons, polyesters, etc. and intrinsically conductive polymers like polyaniline, thiophene, and polypyrrole have been used in textiles incorporating carbon nanotube. Domestic cloths, military wear, workplace wear, sportswear, and healthcare appliances have incorporated polymer/CNT nanocomposite. These nanomaterials has also been applied for the fabrication of intelligent clothes.

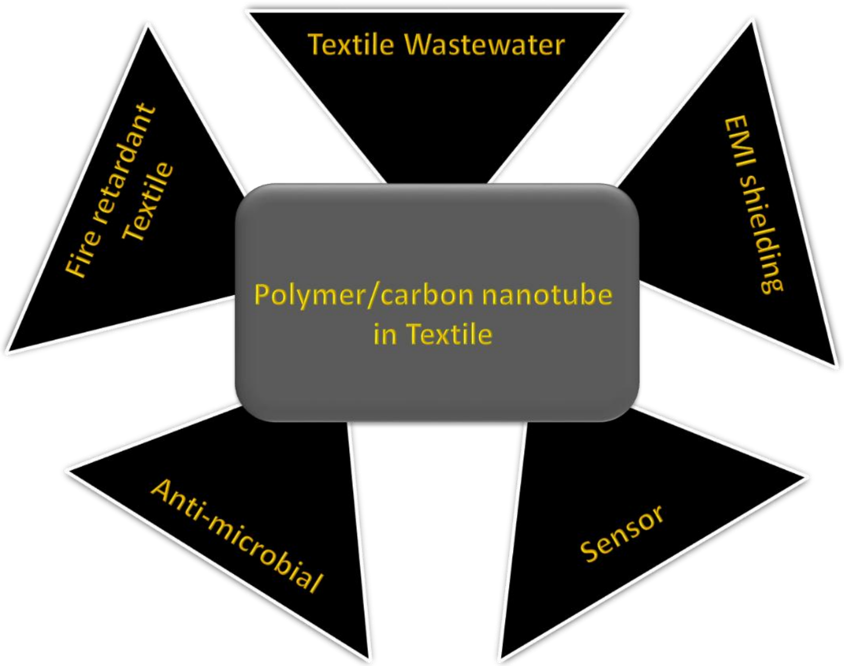

Fig. 2 Polymer/carbon nanotube in textile.

4.1. Fire retardant textiles

Flammability of polymer/CNT nanocomposite has been known in literature [32-36]. The polymer/CNT nanocomposite are flame resistant and thermally anisotropic materials. The heat transmittance through polymer/carbon nanotube nanocomposite cause non-flammability in such textiles (Fig. 3). Polymer/carbon nanotube embedded textile fabrics are thermally stable and flame retardant relative to raw textiles. Compatibility between nanocomposite and textiles has expanded their application in textile industry. The polymer/CNT nanocomposite has caused highly efficient flame retardant fabrics with improved thermal and non-flammability properties.

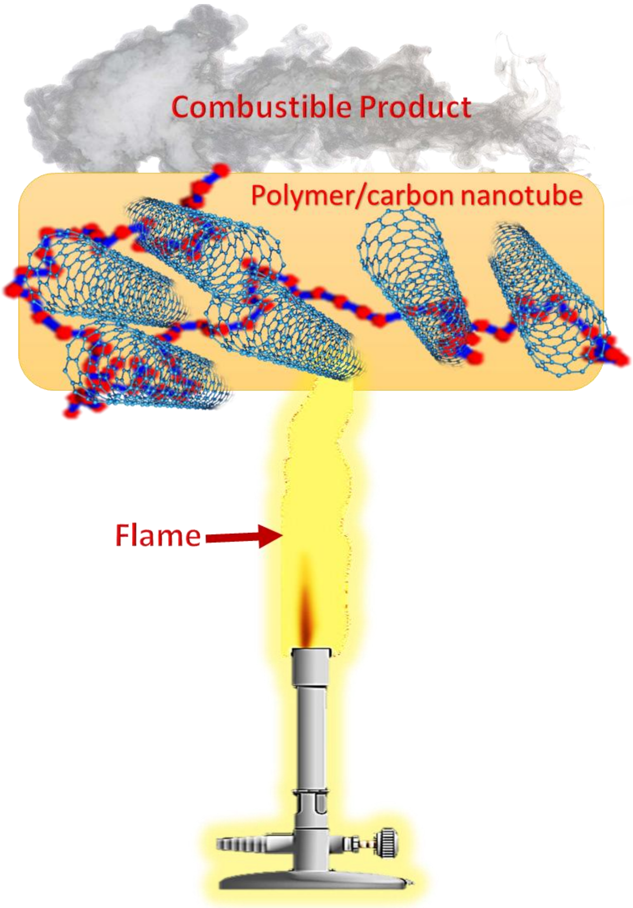

Fig. 3 Non-flammable textile.

4.2. EMI shielding fabric

Polymer/CNT nanocomposite has been used for electromagnetic interference (EMI) shielding. EMI shielding effectiveness relies on nanofiller content and electrical conductivity [37-39]. Development of conducting nanotube network in polymer/CNT has been employed for EMI shielding. The enhanced interfacial contact has found to improve the electrical conductivity. Conducting flexible polymer/CNT fabrics have increased electromagnetic absorption. Modified nanotube and incorporation of metal nanoparticle in nanocomposite has been used to improve the shielding efficiency. EMI shielding efficiency need to be enhanced from 95-99 at >40 dB. The experienced electromagnetic range is from 100-1000 MHz.

4.3. Flexible sensors

Polymer/CNT nanocomposite possess high aspect ratio, thermal conductivity, electrical conductivity, and mechanical strength to be employed for wearable textile sensors [40-45]. Fig. 4 shows design of an electronic sensor.

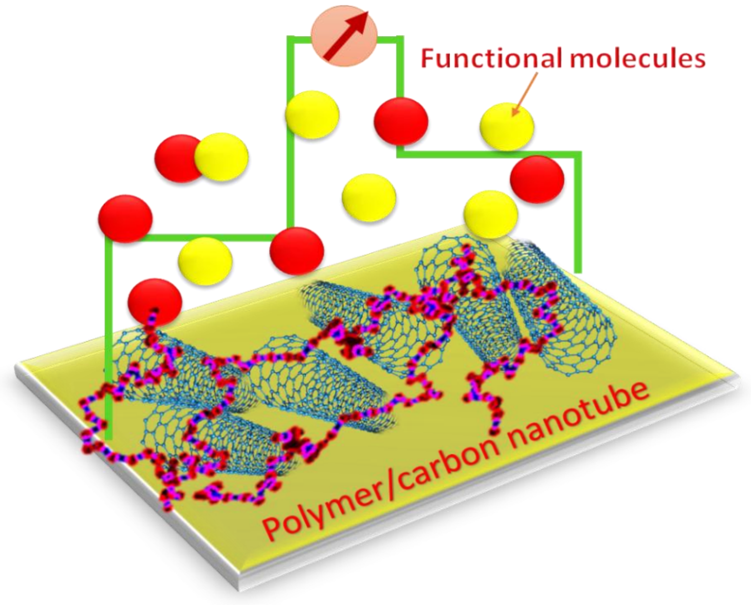

Fig. 4 Textile sensor.

The wearable sensors may generate current of ~10-50 nA. The sensors possess high tensile strain without perceptible degradation. These sensors are flexible, durable, lightweight, conformable, and energy saving. The electrospun polymer/CNT woven and nonwoven fabrics demonstrated fine electrical and mechanical properties.

4.4. Textile wastewater treatment

Toxicity and non-biodegradability of textile wastewater suggest several purification treatments. Polymer/CNT nanocomposite have shown textile waste removal up to 98%. The most important use is the dye removal. Polymer/CNT nanocomposite has shown excellent photocatalytic degradation of dyes owing to electron transfer between polymer and nanotube. The photocatalytic activity of nanocomposite has been studied using methylene blue in aqueous medium (UV irradiation). Photocatalytic nanocomposite need to be improved for wide response range and high efficiency.

4.5. Anti-microbial activity

Another important use of polymer/CNT nanocomposite is in antibacterial fabrics. The nanocomposite have shown strong antimicrobial activity [46, 47]. High surface area, aspect ratio, and tubular shape promote the nanofiller interaction with textile materials. Natural organic matter, cyanobacterial toxins, bacteria, and other pathogens have been efficiently adsorbed/removed by these fabrics.

5. Summary

Carbon nanotube have distinct physical and chemical properties to be employed in textile industry. Polymer/CNT nanocomposite have further enhanced features for textile uses. These materials may cover wide range of textile functions by integrating nanotube with polymer. Both the modified and non-modified nanotube have been used for the purpose. Thus, polymer/CNT nanocomposite have innumerable technical applications in flame retardants, sensors, EMI shielding, textile wastewater treatment, and anti-microbial activity.

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